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This thesis presents an analysies of the Ship Construction and Conversion, Navy, Appropriation cost estimaes for new ship construction during the period 1960-1992. Emphasis is placed on Four specific shipbuilding programs: Guided Missile Destroyer (DDG-51), Fleet Ballistic Submarine (Trident), Attack Submarine (SSN-688), and Guided Missile Cruiser (CG-47). These programs are analyzed to determine how competition/dual sourcing, contract type and the shipbuilding marketplace have influenced the actual costs of these ships. These programs are also compared for the period 1981-1992 to determine if there are any trends or consistency for all of the programs.

The research concludes that the shipbuilding marketplace has a significant influence on actual construction costs of Navy ships. When there is limited commercial work available the shipbuilders may underbid contracts to remain in business. Competition in Navy shipbuilding does not necessarily result in cost savings due to the small number of ships produced and the limited number of competitive shipyards.

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Naval New Ship Construction Cost Analysis and Trends

by

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Lieutenant, United States Navy
B.S., University of North Dakota, 1983

Submitted in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE IN MANAGEMENT

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June 1992

ABSTRACT

This thesis presents an analyses of the Ship Construction and Conversion, Navy, Appropriation cost estimates for new ship construction during the period 1960-1992. Emphasis is placed on four specific shipbuilding programs: Guided Missile Destroyer (DDG-51), Fleet Ballistic Submarine (Trident), Attack Submarine (SSN-688), and Guided Missile Cruiser (CG-47). These programs are analyzed to determine how competition/dual sourcing, contract type and the shipbuilding marketplace have influenced the actual costs of these ships. These programs are also compared for the period 1981-1992 to determine if there are any trends or consistency for all of the programs.

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I. INTRODUCTION

A. BACKGROUND

The declining Department of Defense budget has heightened the need for accurate ship cost estimates to enable the Navy to make supportable resource decisions. Ship cost estimates not only influence the current Navy budget, but they have a significant impact on future budget decisions. The final cost of new construction ships has a direct impact on the design of future naval ships and the ultimate number of ships in the fleet.

This research investigates the Department of the Navy estimating and budgeting experience for the Shipbuilding and Conversion, Navy appropriation (SCN). Emphasis is placed on new construction programs and includes a comparison of original budget estimates with the actual ship end cost. Since shipbuilding is a large capital venture requiring a lengthy construction period it is essential that budget estimates be realistic to enable decision makers to make informed resource allocation decisions. This study analyzes the budget decisions of past programs in order to learn from those decisions and thereby make more confident projections about future shipbuilding program budgets.

B. OBJECTIVE

The focus of this thesis is on the Ship Construction and Conversion appropriation (SCN) during the period 1960-1992. Four major new shipbuilding programs were selected for detailed data analysis. They are: the Fleet Ballistic Submarine (Trident), Attack Submarine (SSN-688), Guided

Missile Cruiser (CG-47), and Guided Missile Destroyer (DDG-51). These programs were selected as the ship construction programs to examine based on the large monetary value of each program. In addition, all four programs currently have ships under construction and these ships will be utilized by the Navy well into the twenty first century. All programs except the DDG-51 have current and comparable data for the last 10 years. The DDG-51 has data for only seven years. However, the DDG-51 is the newest of the four programs. It is projected to have new ship construction appropriations for several years.

Program documents and budget estimates were reviewed to identify specific program events and to compare the original estimates with the actual cost. Each program was reviewed individually and then compared with the other programs to determine if a consistent or predictable pattern emerged for all of the shipbuilding programs.

C. RESEARCH QUESTION

The primary question is : why are there deviations between the estimated end cost for new ship construction and the actual end cost? The secondary questions include: are there patterns or trends which cause deviations in the cost, and what can be done to modify or correct the deviations?

D. SCOPE AND LIMITATIONS

The predominant focus of the thesis is on new ship construction over the past ten years. However, the total SCN account was examined from 1960 to 1991 to check for long term trends. During this period the shipbuilding industry and the budget estimates went through multiple changes, experiencing both cost underruns and overruns. For the period 1981 to the

present a detailed analysis is conducted on the four selected new ship construction programs.

E. LITERATURE REVIEW

The information used in this thesis comes from a literary search and a research trip to Washington D.C. Some of the more pertinent information was obtained from Department of Defense instructions, and previous studies on cost estimation, and cost growth.

Data was gathered by reviewing Naval Comptroller (NAVCOMPT) budget documents and NAVAL SEASYSTEMS COMMAND (NAVSEA) cost reports for both the overall SCN account and the individual programs. Several days were also spent at both NAVCOMPT and NAVSEA offices in Washington D.C. interviewing key personnel involved in the SCN budget process. Other more general information was obtained from the Shipbuilders Council of America quarterly reports and from Jane's Fighting Ships.

F. ORGANIZATION OF THE THESIS

The thesis research will begin by describing the magnitude of the SCN account. Various theories and reasons for cost growth will then be discussed. The research data is organized into four periods: Period I (1960-1971), a high demand period for Navy shipbuilding; Period II (1971-1975) a period of industrial revolution and high rates of inflation; Period III (1976-1981) a time of stability in cost estimates and changes in budgetary procedures; and Period IV (1981-present) a period of fluctuating demand (force cutbacks). Following the overall historical trend is an in-depth analysis of the four selected programs and how the factors of cost growth have impacted these programs over the last ten years. The conclusion section provides a projection on what

may be expected in the future regarding SCN budget estimates. This projection is based on the data analysis from reviewing the historical trends of the four selected ship types.

The next section provides important background information on the uniqueness of the Navy appropriation entitled Shipbuilding and Conversion, Navy or SCN.

II. BACKGROUND

A. SHIPBUILDING AND CONVERSION

The Shipbuilding and Conversion, Navy, Appropriation (SCN) is a multibillion dollar fund, accounting for approximately 10 to 15 percent of the Department of the Navy Total Obligational Authority and 35 to 45 percent of the total annual procurement budget. The SCN budget finances the construction of new ships and the conversion of existing ships, including hulls, mechanical and electrical equipment, electronics, guns, torpedo and missile launching systems, and communications systems. It also finances procurement of long lead time items for ships for which authorization will be requested in the following fiscal year. [REF. 1 pg. 4-79]

With the exception of FY 1983 and FY 1988 when aircraft carriers were funded for construction, the dollar value of the SCN appropriation has been steadily declining over the last ten years, as shown in Figure 1. This is significant since the number of ships purchased by the Navy has remained virtually constant over the same time period, as shown in Figure 2.

Although the SCN appropriation is only 10-15 percent of the total Navy budget, the dollar amount is significant. The 1990 SCN appropriation was $9.3 billion dollars. However, when a new combatant such as the DDG-51 costs an average of $819 million dollars [REF. 2 pg. 6] the quantity of ships that can be acquired is limited and proper utilization of resources becomes crucial. Since the Navy adheres to a "full funding" policy, as directed by the Department of Defense, [REF. 1 pg. 6-89] a SCN procurement item has been authorized by Congress must be funded in total at all times. However, since

Figure 1

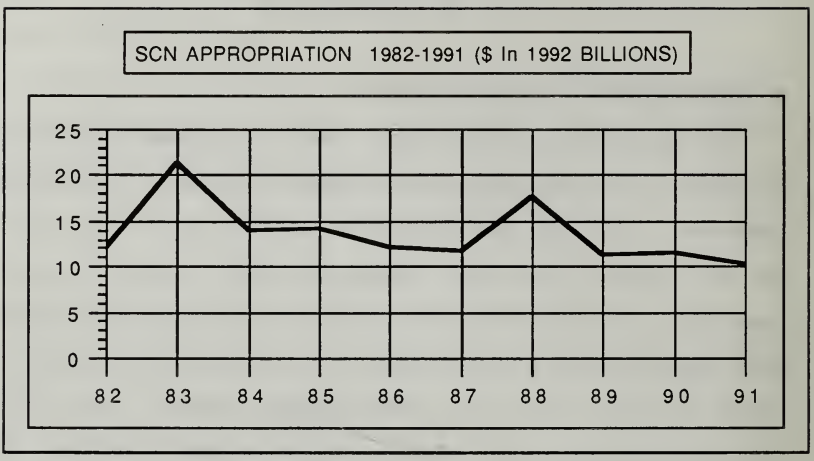
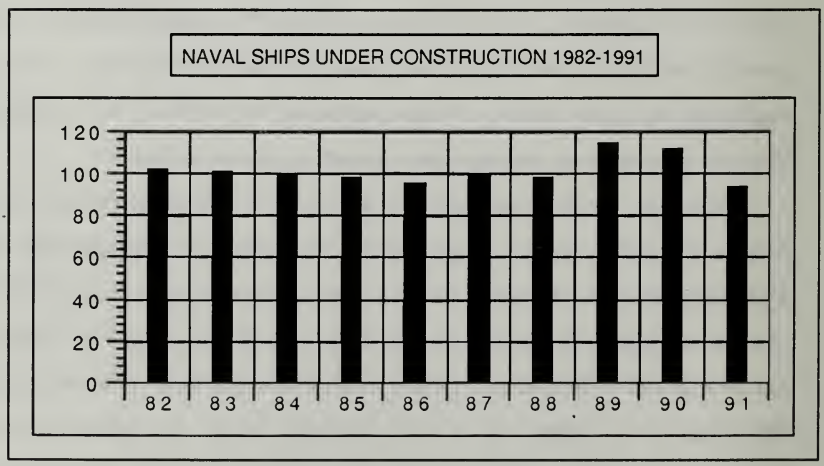


Figure 2



ship construction is such a long term program, funding may have to be modified. The Ship Construction Adjustments (SCA) can be used to meet changes in expected end costs. (Appendix A)

Shipbuilding requires a time period from five to eight years to complete the average new construction vessel. The DOD full funding requirement means that total end cost must be estimated for ships that are still years from completion. Thus, many changes can occur during the construction process that may affect the eventual ship end cost. With the decline in the defense budget and the subsequent decline in the SCN appropriation, it is imperative that the Navy have accurate estimates of ship end costs. Every dollar spent for construction becomes significant. It is with this precept that the reasons for cost growth are examined to determine if there are any consistent or predictable factors that affect the cost estimates.

B. COST GROWTH

Many factors can impact the ship cost estimates. Some of the factors most commonly considered as contributing to cost growth in shipbuilding programs are investigated in this research. They are:

- competition/dual source production
- contract type
- commercial/military market

This research will focus on these factors to see how they have affected cost estimates over the last 30 years.

C. COMPETITION/DUAL SOURCING

DOD decision makers are under a mandate to use scarce resources wisely, due to the growing pressures from the Administration, Congress, and the

American public. It is a widely held belief that competition can produce great savings in acquisition costs. However, savings cannot be expected from every competitive procurement. Thus, the theory of competition in the shipbuilding industry will be examined.

There is a deep-seated belief that the best approach for Government procurement is solicitation of price offers from a maximum of qualified sources. In his memorandum (1985) accompanying Recommendation 32 of the Acquisition Improvement Program (AIP), Deputy Secretary of Defense Frank C. Carlucci said, in part:

> "The value of competition in the acquisition process is one of our most widely accepted concepts. We believe that it reduces the costs of needed supplies and services, improves contractor performance, helps to combat rising costs, increases the industrial base, and ensures fairness of opportunity for award of government contracts. [REF. 3 pg. 10]

Thus the notion of competition has manifested itself in the procurement of defense weapons systems. Current DOD instructions state that defense systems, subsystems, equipment, supplies and services shall be acquired on a competitive basis to the maximum extent practicable as a means of achieving cost, schedule, and performance benefits. [REF. 4 pg. 1-6] This commitment to competition stems from the widely held belief that better products are provided at lower prices in a competitive rather than non-competitive environment.[REF. 3 pg. 11]

D. BENEFITS OF COMPETITION

There are many perceived benefits from competition. Cost savings has been the primary benefit of competition. However, there are additional reasons for competition, they are: increased contractor efficiency, reduced risk, mobilization/surge capability, and political benefits. Realization of one type of benefit may not necessarily be consistent with realization of another. Each of these reasons for introducing competition by using multiple sources is discussed below.

1. Cost Savings

The classic rationale for competition is that competitive markets will result in the lowest cost for a product. The justification for introducing competition in procurement is the opportunity to achieve a lower unit production cost. [REF. 5 pg. 45]

A 1965 statement by then Secretary of Defense Robert McNamara to the Joint Economics Committee of Congress asserted that savings on the order of 25% or more generally resulted from a conversion to competitive procurement from a sole source. [REF. 6 pg. 18] While there are questions about the generality of the savings, the fact remains that, in a competitive market environment, the price paid by the buyer tends to move in the direction of the minimum costs of production. [REF. 7 pg. 32]

Cost growth as it relates to Navy construction may indicate that with competition, the contractors are submitting low bids in order to secure the Navy contract. However, if actual costs tend to decrease with the introduction of a second source of production, competition may actually encourage

efficiency and therefore lower costs to the Navy. Thus, competition may have different effects on cost growth and actual costs.

2. Increased Contractor Efficiency

Use of multiple producers may arguably result in increased contractor efficiency as reflected in such items as product quality control, adherence to delivery schedules, and more rapid technological progress. For the producing contractor, the motivation for increased efficiency is the improvement in the negotiating position for later contract awards. A fresh look at the hardware by competent engineers of the competing firms often results in technical improvements and better problem solving. [REF. 3 pg. 14]

3. Reduced Risk

The use of multiple producers may reduce several types of risk. Technical risk may be reduced during both design and production phases. Employing more than one contractor increases the likelihood that stumbling blocks will be overcome or alternative options created by using differing approaches or techniques. Using second source production facilities decreases the likelihood that physical destruction of a shipyard or strikes will slow or stop production of vital items. Use of more than one producer also reduces the risks to the government associated with contractor labor difficulties and financial instability. [REF. 3 pg 15]

4. Mobilization/Surge Capability

Another claimed benefit of competition, particularly dual sourcing, is that the U.S. industrial base will have a greater capacity to "surge" production in the event of a war or national emergency. Traditionally the objective of maintaining a strong industrial base is to be able to provide an

increased quantity of virtually all systems in the current force structure. Proponents of the mobilization base point to the classic "gearing up" of the industrial base prior to the American entry into World War Two. Successful mobilization made a vital contribution to victory in that war. For this reason, maintenance of the mobilization base is considered essential and is a factor in the awarding of weapon system contracts. [REF. 8 pg. 21] However, in the current environment the need for mobilization may not be a realistic justification for dual source production, since the threat of an extended conventional war has diminished. [REF. 8 pg. 33]

5. Political Benefits

Awarding contracts to more than one source often contributes heavily to successful funding for weapon programs in the annual budget battle. Major contract awards generally create significant numbers of new jobs in the congressional districts where the winning contractors are located. [REF. 7 pg. 3]

E. CONTRACTS

The nature of the contract that is written with the shipbuilder also has an impact on the end cost of the ship compared to the estimate. The distinguishing feature among the various kinds of contacts used for Naval shipbuilding is the way risk is shared between the Navy and the contractor. The risk sharing arrangement is reflected in the contractor's escalation clause and incentive features. [REF. 9 pg. 4]

The risks of price changes due to inflation are partly borne by the Navy through escalation clauses. These clauses increase the allowable labor rates and material fees to keep pace with Bureau of Labor Statistics (BLS) indices of

labor and material prices over the life of the program. The SCN appropriation has been allowed to budget for escalation due to the extensive period of time to construct new ships.

1. Incentive Provisions

Incentive provisions of the contract determine how the cost variance risk of the program is to be shared between the contractor and the Navy. Three basic types of risk-sharing agreements are used in shipbuilding contracts: Firm Fixed Price (FFP), Fixed Price Incentive (FPI), and Cost Plus Award Fee (CPAF). (Appendix A)

The type of contract directly affects the bid price for ship construction, since contractors will bid higher when they must bear more of the program's risks. On the other hand, the competitive pressures of the bidding process are likely to induce contractors to lower their bid. Whether the contractor's bid understates or overstates expected costs, depends at least in part, on the balance of these two forces

Considering the litigation possibilities, a contractor may be more likely to willingly underbid a contract. Even under FFP contract, contractors may point to cost overruns and claim that for one reason or another the Navy is responsible. Unfortunately, when the Navy and the contractor cannot agree as to the responsibility for cost overrun, the final outcome is settled by Requests for Equitable Adjustments. (REA) (Appendix A). The contractor may recoup some portion of the underbid. If contractors can expect to receive compensation through the litigation procedures, they may incorporate this into their bids. This may exacerbate the underbidding problem. In some cases, this ex post compensation may raise the cost of a ship

to the Navy above the cost that would result from an initially higher, more realistic bid. [REF. 9 pg. 8]

F. COMMERCIAL/MILITARY MARKET

Planning for ship production is done several years in advance of the actual ship construction to acquire the necessary plant capacity and equipment required in order to produce at the most efficient rate. This expenditure of resources is accomplished in anticipation of future contracts and expected production. When commercial business is readily available efficiency can be expected in the shipbuilding industry due to continuous production. However, ships cannot be produced at the most economical rate when quantities do not utilize the shipbuilder production capacity efficiently. Increased costs and inefficiencies occur when the quantities being produced result in idle plant capacity. [REF. 10 pg. 22] Thus, the workload of the contractor determines the utilization and expectations of plant capacity, this utilization may then determine how well the overall costs of a program compares to the estimates.

When there is ample commercial work available the Navy can expect to incur increased costs and delays for ships due to commercial work being more profitable. The workload of commercial ship construction affects the cost of Navy ships by the allocation of overhead costs. When there are more commercial ships being constructed, the overhead is distributed over a greater numbers of ships. This lowers the overhead cost per ship. Off setting this lower overhead rate is the fact that commercial ships are less complex to build than Navy ships. Due to the technological requirements and sophisticated systems that must be installed on Navy ships, the construction process takes

longer and requires more skilled labor. A commercial ship can be constructed more quickly and at less cost than a Naval vessel. Therefore, the emphasis for shipbuilders may be to concentrate on commercial construction and delay the more costly Navy ships. When there is limited commercial business available, competition between contractors for Navy ship contracts may result in lower than expected estimates. These bid estimates may be lower than actual construction costs as shipbuilders attempt to fill the capacity of shipyards with Navy construction contracts.

G. SUMMARY

The various reasons for cost growth and factors that affect ship construction costs have been presented in this chapter. The next chapter will discuss what has happened to the SCN appropriation and ship cost estimates over the last 30 years by examining the shipbuilding industry, economic conditions and other factors that have affected Naval ship construction costs.

III. HISTORY

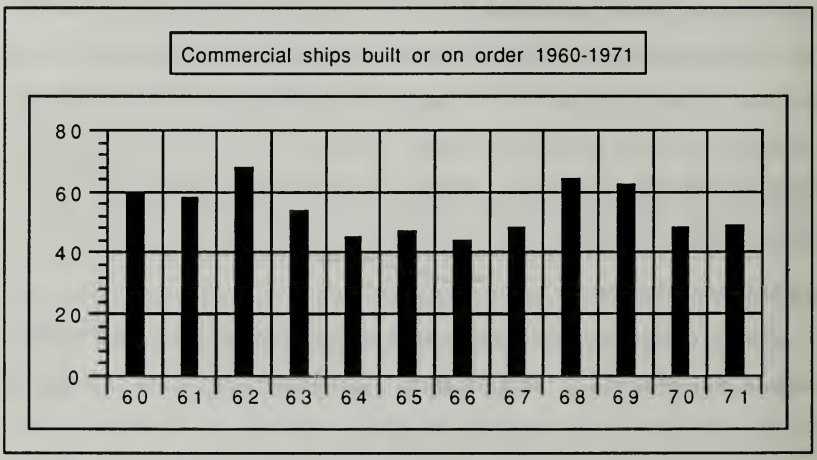
To analyze the effects that the factors presented in chapter II have had on shipbuilding and cost estimates, this research will divide ship construction data into four periods: Period I (1960-1971), Period II (1971-1975), Period III (1975-1981), and Period IV (1981-Present). For periods I-III, general results are discussed using aggregate SCN data. For Period IV, specific analysis was conducted on four programs: Guided Missile Destroyer (DDG-51), Fleet Ballistic Submarine (Trident), Attack Submarine (SSN-688), and Guided Missile Cruiser (CG-47).

A. PERIOD I (1960-1971)

During this period there was heated competition for Navy shipbuilding work. Although some commercial work was available, it was not enough to fill the capacity of the existing shipyards. As shown in Figure 3, the commercial shipbuilding workload declined in the middle of the 1960's. However, as shown in Figure 4 the Navy was increasing the number of new construction ships during this time period. Because competition for shipbuilding contracts was keen for this increased Navy workload, contracts were awarded for considerably less than the cost estimated and budgeted by the Department of the Navy. This occured despite the fact that new and complex ship specifications (e.g. dynamic shock analysis) were being introduced at the time. The contract form for these awards was Firm Fixed Price (FFP). Thus, the shipyards were limited in their flexibility and found themselves in financial difficulty, due to the nature of the contracts and the

increased complexity of Navy Ships. They were therefore required to submit claims to the Navy for compensation adjustments. [REF. 11 pg. 9-6]

Figure 3

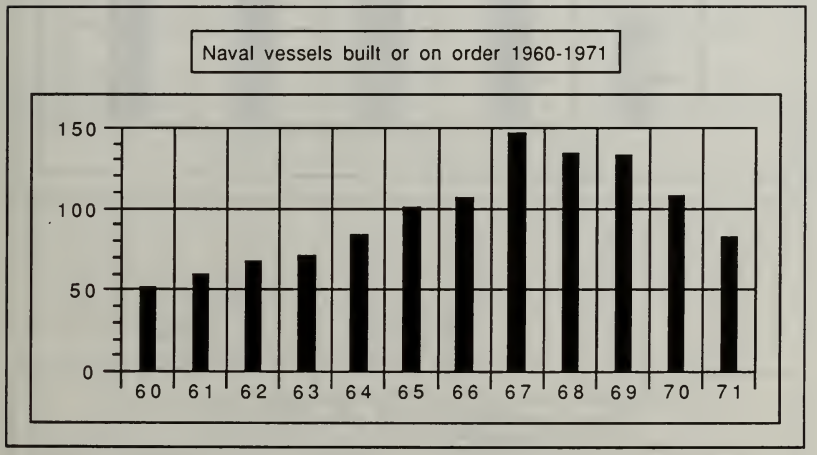


Research conducted by the Office of Naval Research, titled "Recent Trends in the Shipbuilding Industry and the Implications for Naval Ship Procurement," summed up the trends of Period I 1960-1971 as follows:

- A stable work load is necessary for the efficient operation of the shipbuilding industry. When the work load is slack or unstable, planning is adversely affected since estimates for future construction are uncertain.
- Navy contracts have not been conducive to the learning process since contracts are awarded for small numbers of technically complex ships.

- The number of Navy ships constructed has increased, thus the composition of skills in the shipbuilding industry has changed, since naval and commercial work require different mixes of skills. [REF. 12 pg. 35]

Figure 4



B. PERIOD II (1971-1975)

During the period from 1971 to 1975, contracts for a total of 108 ships were awarded, including 81 new construction ships. [REF. 13 pg. 31] Figure 5 and 6 show the commercial and Navy workload for new ship construction in this period.

Figure 5

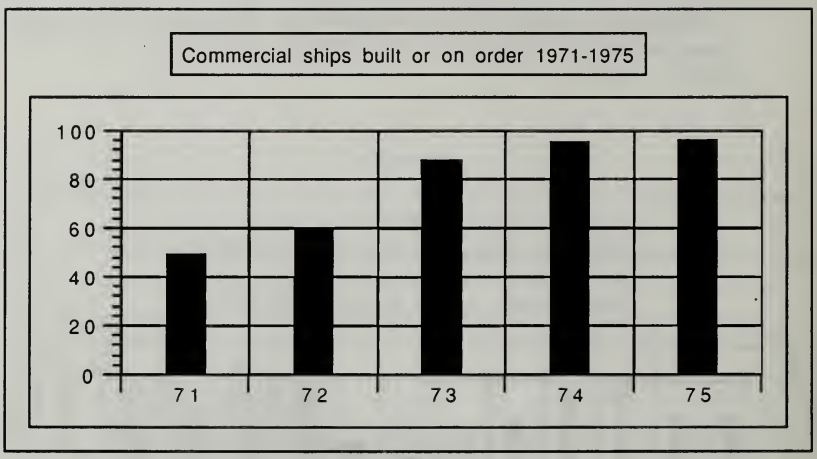
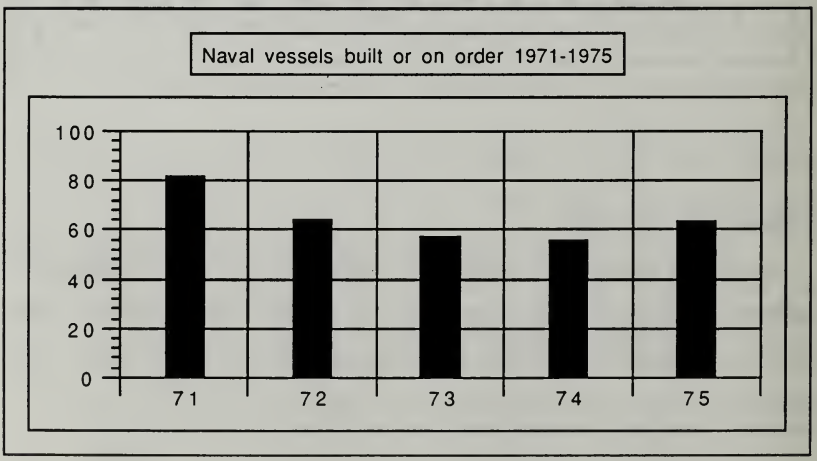
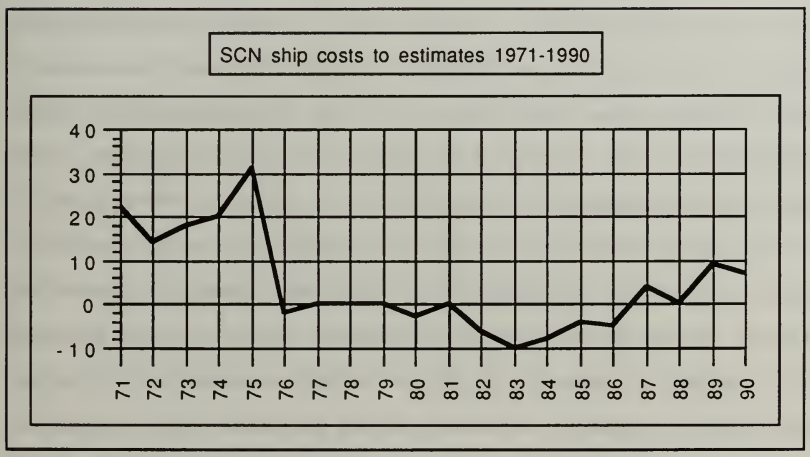


Figure 6



Despite the abundant commercial workload and presumably lower overhead rates (because overhead was allocated over a large workload), there was significant cost variance between the Navy budget estimates and the final program cost. As is depicted in Figure 7, the variance was on the order of 20% for this period, with a swell of 30% in 1975. [REF. 14 pg. 33]

Figure 7



Many factors contributed to the variance between the budget estimates and the final program cost. Manpower and production resources were being stretched to meet both commercial and Navy efforts. In addition, technological developments during this time had a large impact on the shipbuilding labor force. Progress in nuclear propulsion, automation of

industrial activities, solid state electronics, supersonic and space flight all had a revolutionary effect on industry. [REF. 12 pg. 15] This "industrial revolution" caused the costs of Navy ships to increase. [REF. 12 pg. 17] The emerging industries were competing for skilled labor. Thus, workers were leaving the shipbuilding industry for better earnings elsewhere. Hourly earnings of other industries had increased at a greater rate than the shipbuilding industry. Thus, shipyards were unable to retain the skilled work force required to sustain construction. [REF. 12 pg. 18]

This lack of a skilled work force caused the shipbuilding industry to rely on new and less experienced workers when the industry workload exceeded capacity. [REF. 12 pg. 19] Since commercial shipbuilding work was normally more profitable than Navy work, it would be reasonable to expect shipbuilders to use their most experienced labor in commercial work. Manpower and productivity for Navy construction suffered. [REF. 13 pg. 31]

New construction starts during this time period included the Nimitz Class aircraft carrier, Los Angeles and Trident submarines and Perry Class Frigates. Due to the complexity of these ships, the skills required exceeded those normally encountered in commercial ship construction, i.e. nuclear engineering, ship silencing and shock proofing, etc. [REF. 14 pg. 5] The degree of complexity in naval construction was well stated by John Diesel, President of Newport News Shipbuilding, when he noted in 1974 that designing and planning an aircraft carrier involves "more than 2,400 miles of blueprints, 22,000 work packages and 16,000 drawings." [REF 15 p.855] Thus, Navy construction work was delayed (slipped) and costs increased as shipbuilders adjusted to the emerging technology. [REF.13 pg. 24] In addition, shipbuilding

management failed to adjust procedures and controls to deliver the more complex ships.

During this time period the inflation rate was greater than expected. Double digit inflation caused vendor quotes to be unstable and unpredictable. However, the inflation rate for shipbuilding indices was greater than that of the consumer price index for both labor and material. This caused cost overruns by the contractors, and thus the large discrepancies between actual costs and estimates. [REF. 14 pg. 11-15]

C. PERIOD III (1976-1981)

Between 1976 and 1981, budget performance was relatively stable with minimal variance between the budget and Expected Cost at Completion (EAC), as shown in Figure 7. During this period, a total of 124 ships construction awards were made, of which 120 were new construction.

Though the quantity of ships constructed during this time was similar to the workload of the earlier period of 1971-1975, as shown in Figures 8 and 9, major adjustments in cost estimating, budgeting, and contracting greatly improved performance to budget. In 1975, the indices for escalation were changed to more accurately reflect the actual inflation rate for ship construction. [REF.16 pg. 6-31]

Budget reserves were encouraged by budgeting for program manager growth and for future characteristic changes. Budget lines were established for cost growth and escalation, by establishing target cost and ceiling cost. [REF. 16 pg. 9-6] This allowed for more flexibility and contingency planning. Changes in the economic and industrial environment also assisted in making EACs

Figure 8

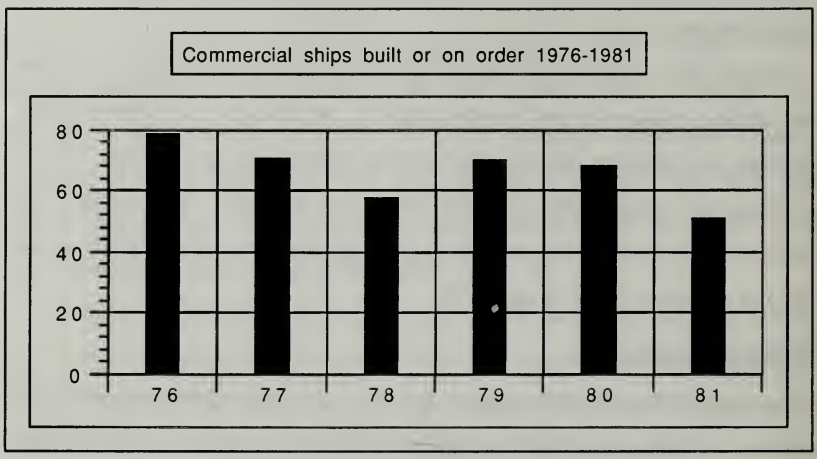
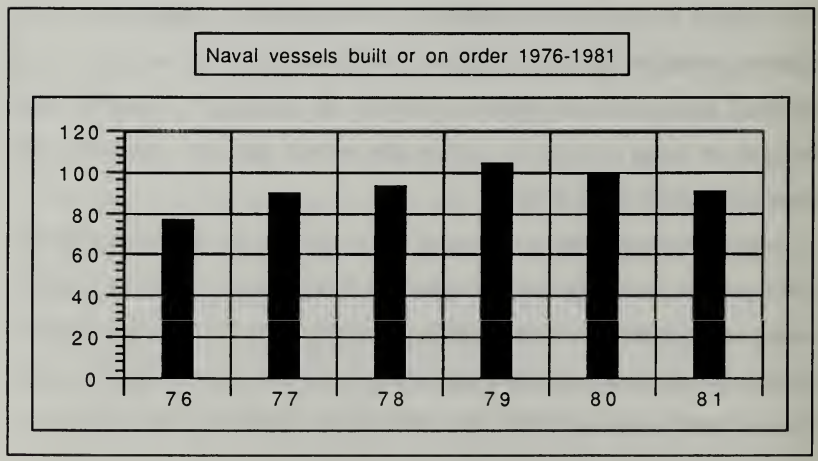


Figure 9



more predictable. In particular, interest rates had fallen and inflation retreated back to single digits.

D. PERIOD IV (1981-1991)

Until 1981, the shipbuilding industry was the indirect beneficiary of very generous government subsidies. Ship buyers received a fifty percent subsidy from the government to construct commercial ships, providing ample business for domestic shipyards. [REF. 17 pg. 18]

In 1981, the Government eliminated the Maritime Administration construction-differential subsidy program. When the subsidies ceased, the domestic commercial market simply collapsed. New orders dropped severely. Between 1982 and 1987, domestic ship building capacity declined by about one third. Forty one shipyards closed, with a loss of 32,000 employees. This all occured during a period when the worldwide commercial shipbuilding market remained strong. [REF 17 pg. 20] The Shipbuilders Council of America reported that since 1987 only three commercial ships have begun construction. All three were within the last two years. [REF. 17 pg. 21]

As Figure 10 exhibits, 49 commercial ships were under construction or on order in the United States in 1981. This number has been steadily declining ever since. Figure 11 shows that the construction of Navy ships has remained relatively consistent over the last ten years.

From 1981 until present the number of active shipyards in the U.S. has declined from 25 to 13. [REF. 17 pg. 1] Thus, over this time period, the principle business income for shipbuilders has been from Navy construction.

Figure 10

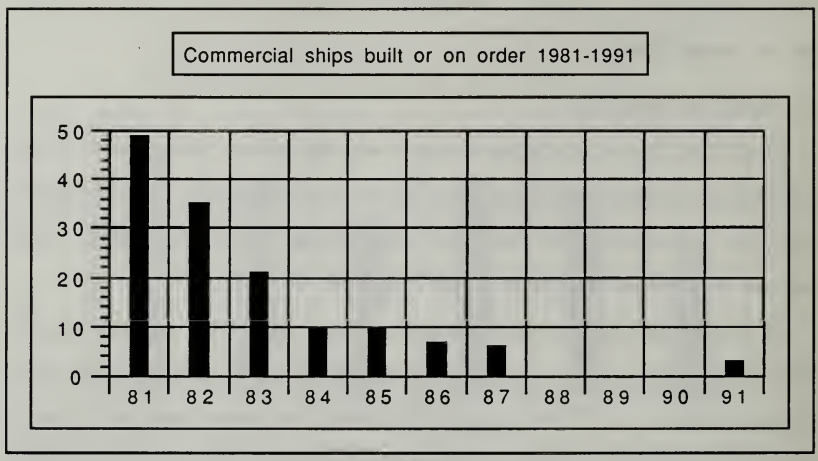
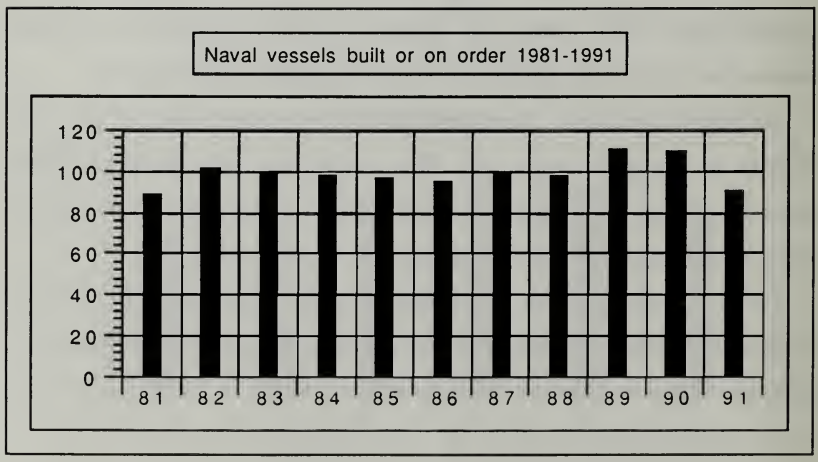


Figure 11



Shipbuilders reacted to the decline in commercial ship construction by aggressively seeking Navy work and contract prices were at an all time low. [REF. 18 pg. 5]

Economic and industrial factors also fostered increased variance from the budget. Due to the decline in commercial shipbuilding, overhead rates increased, as there were fewer units against which to apply overhead charges. Anticipation of a 600 ship Navy and fierce competition among shipyards were reflected in overly optimistic pricing during the early 1980's and subsequent cost growth for the SCN appropriation in later years, as shown in Figure 7.

E. SUMMARY

This section of the thesis discussed how the SCN appropriation has evolved over the years. Particular attention was placed on how the commercial shipbuilding industry has reacted to changes in the economic environment over the last 30 years, and subsequently, the effect on Navy shipbuilding during this time period. The next chapter will present the cost categories for ship cost estimates and present the methodology for the study of the four specific ship building programs presented in Chapter I.

IV. METHODOLOGY

A. DATA DESCRIPTION

In order to forecast future trends, it is necessary to have a data base and make certain assumptions. Makridakis and Wheelwright state that quantitative forecasting can be applied when three conditions exist:

-there is information about the past

-this information can be quantified in the form of data

-it can be assumed that the pattern of the past will continue into the future.

This last condition is known as the assumption of constancy and is an underlying premise of all quantitative and many technological forecasting methods.[REF. 19 pg. 35]

The analysis in this thesis is based on data derived from various sources within the Department of Defense and the U.S. Navy. The majority of the information was obtained from Navy Comptroller (NAVCOMPT) budget documents. The end cost of a ship is derived from 12 cost categories that make up the total cost of the ship, they are:

- Construction Plans
- Basic Construction
- Change Orders
- Electronics
- Propulsion
- Hull/Mechanical/Electrical
- Other Costs
- Ordnance
- Future Characteristic Changes

- Escalation
- Project Managers Growth
- Total Cost

Each category estimates specific components of ship construction. [REF. 13 pg. 6-1] This information was obtained for four programs during the time period 1981-1992: Guided Missile Destroyer (DDG-51), Fleet Ballistic Submarine (Trident), Attack Submarine (SSN-688), and Guided Missile Cruiser (CG-47). The following is a brief description of each of the 12 cost categories.

B. COST CATEGORIES

1. Construction Plans

On the basis of contract drawings and specifications prepared by NAVSEA, detailed construction plans are developed by the shipbuilder. The cost of these efforts are charged to this category. This category also includes related engineering calculations, computer programs, contractor-responsible technical manuals, damage control books, ship's selected records, and mock-ups. The lead ship will normally carry the cost burden for this category, since the majority of these costs are considered to be nonrecurring. Follow ships may have costs in this category because a lead yard or planning yard has been assigned to keep the engineering development current for follow on ships. [REF. 16 pg. 6-28]

2. Basic Construction

The Basic Construction category includes all allowable labor, overhead, and material incurred in constructing the ship. It also includes an amount for the cost of money and profit. In addition to shipbuilder-furnished

material, the price includes the cost for installing all Government Furnished Material (GFM).

The Navy, requires the shipbuilder to integrate GFM into the ship, according to the ship specifications, as part of the ship construction process. This includes receiving, storing, installing and performing checkout and tests of the GFM items. This process is complex in its own right and is often a construction related cost driver.[REF 16 pg. 6-3]

3. Change Orders

Over the course of new ship construction, there are numerous changes from the initial plan. There are various reasons for these changes, including:

-Incorporating state-of-the-art improvements that come about during the lengthy construction period.

-Correcting "mistakes" that surface in transition from two-dimensional drawings to the three-dimensional lead ship final product

-Incorporating safety items that emerge during construction.

-Including Improvements that are generated by operational forces afloat.

-Repairing or modifying GFM

These technical changes are accomplished by change orders. There are two kinds of change orders, Headquarters Modification Requests (HMRs) and Field Modification Requests (FMRs). HMRs are initiated by NAVSEA. FMRs are initiated by the on-site Navy Supervisor of Shipbuilding Office and must be less than a set dollar limit. However, the end cost to the change orders is not identified by either HMRs or FMRs. They are totalled for the entire change order category. [REF 16 pg. 5-6]

4. Electronics

The items in this category, both hardware and software, include electronics production components, training support equipment, test and engineering services and repair parts associated with installation. [REF 16 pg. 5-7]

5. Propulsion Equipment

The GFM Propulsion H/M/E category may or may not be part of the end cost. In most cases, the propulsion components for conventionally powered ships are shipbuilder-responsible, contractor furnished material (CFM). In this case, the propulsion category is not used. When propulsion items are provided as GFM rather than CFM, this category is included. GFM propulsion items can include nuclear reactors, cores, turbines, gears, and other selected propulsion items.[REF. 16 pg 5-8] The propulsion category is always used in the case of nuclear-powered ships, since nuclear reactors and cores are historically provided to shipbuilders as GFM. This is due to the standardization and safety precautions mandated for nuclear propulsion systems.

6. Hull/Mechanical/Electrical

Items included in this category, both hardware and software, are Hull, Mechanical and electrical (H/M/E) equipment, H/M/E deep submergence systems, small boats, special vehicles, environmental protection equipment, training support equipment, H/M/E engineering services, repair parts associated with installation of H/M/E equipment, and all medical equipment furnished by the Naval Medical Command.[REF. 16 pg. 5-8]

7. Other Costs

This category is a catch-all summary of a number of work elements. This category includes Planned Maintenance Subsystems (PMS), equipment transportation, travel in support of construction, engineering services and SUPSHIP material. [REF. 16 pg. 7-8]

8. Ordnance

Items included in this category, both hardware and software, are fire and missile control systems, search radars, missile launching systems, gun systems, training support equipment, test and integration services, and other ordnance equipment. Due to the complex and sophisticated systems installed on Navy ships, ordnance equipment is supplied to the shipbuilder as GFE. [REF 16 pg. 5-7]

9. Future Characteristic Changes

Future characteristic changes is a reserve account that is established for future changes in the ship construction process. The amount reserved for this purpose depends on basic construction cost, number of ships in the program, the development nature or complexity of the ship and the likelihood of incorporating new capabilities into the ship during the construction process. The reserve amount may be used to take advantage of technical breakthroughs, which make possible the installation of the latest electronics, communications and weapons equipment on ships still under construction.

10. Escalation

Contracts for ship construction include an escalation clause to reimburse the shipbuilder for inflation changes in the shipbuilding industry

over the life of the contract. The estimated amount required is contained in the Escalation Reserve category. [REF 16 pg. 2-11]

The cost estimates for escalation are estimates of what inflation is expected in the shipbuilding industry. The rates are set by the Office of the Secretary of Defense (OSD) in conjunction with the Office of Management and Budget (OMB) and are adjusted annually. [REF. 16 pg. 6-30]

11. Project Managers Growth

Project managers growth or reserve is a source of contingency funds for unanticipated future events. The funds are provided in each budget estimate to cover potential problems and necessary actions that may surface during the lengthy ship construction process. [REF 16 pg. 8-4]

12. Total Cost

The last category, total cost, is a cumulative amount for all the cost categories and represents the total estimated end cost of the ship.

C. METHODOLOGY

The data for each ship class was compiled from NAVCOMPT P-8 exhibits (Appendix A) for each year FY 1981 to FY 1991 to obtain a cumulative comparison of the total funds appropriated and actual costs over the ten year period. This information was then reviewed to determine what areas of ship construction are the "cost drivers" in terms of cost differences from the original estimate. These "cost drivers" were then investigated further, to determine what has happened in these areas to cause costs to change. The deviation from the original appropriation was stated as a percentage of the original appropriation for each year. This allows data to be compared from year to year and across the four selected ship programs. By comparing

percentage changes, programs can be compared with each other because costs have been normalized.

D. SUMMARY

This section of the thesis discussed the data that was utilized for the analysis of ship construction costs and cost estimates and the methodology of analyzing the data. The next chapter will present the four specific shipbuilding programs and analyze what has happened to these programs over the time period 1981-1991.

V. DATA PRESENTATION

This section will analyze the DDG-51, Trident, SSN-688, and CG-47 programs in more detail to determine what happened to these programs over the ten year period 1981-1991. The individual ship class data is presented in three basic categories. First, the number of ships that have been constructed by program year is presented. This basic profile data will provide an understanding of how the program has progressed since initiation of new construction. Secondly, the total dollar difference between appropriations and actual cost is calculated for each program for the ten year period. This total is a cumulative total for the entire ten year period. It shows which areas of construction have had the most significant cost changes for each program. Third, the original estimated cost for each year is compared to the actual total cost to determine any dominant cycles or trends. For ships still under construction, the estimated cost at completion (EAC) is compared to the original cost estimate. This analysis may reveal any significant changes in a program that cannot be determined on a cumulative basis. Each of the programs presented are at different stages of maturity. The DDG-51 is in the beginning stages of production, the other programs are near completion.

A. GUIDED MISSILE DESTROYER (DDG-51)

The DDG 51 is the replacement for older retiring battle force guided missile destroyers. Its capabilities include a combat system that can perform simultaneously in Anti-Air, Strike, Anti-Surface, and Anti-Submarine warfare missions. The DDG-51 can operate as part of a Carrier Battle Group, Surface Action Group, Amphibious Task Force, or Underway Replenishment

Group. The ship displaces less than 8300 tons and is designed with a gas turbine propulsion system. The design provides for outstanding combat capability and survivability characteristics. [REF. 20 pg. 479] Bath Iron Works, Maine was awarded the lead ship contract in 1985 with Ingalls Shipbuilding Incorporated, Mississippi established as the second source producer in 1987. All contracts for new ship construction are Fixed Price Incentive. The Navy currently plans to acquire at least 49 guided missile destroyers, with production shared equally by the contractors. [REF. 2 pg. 2]

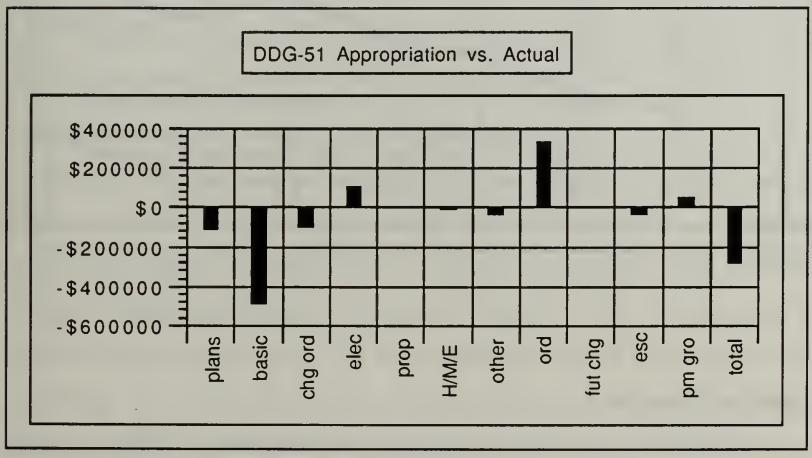
The number of ships that have been constructed or are under construction by program year is presented in Table 1. These 17 ships have been funded and represent approximately one third of the total ships expected to be constructed. The majority of ships constructed have been started within the last three years. The planned construction rate for the next five years is three to four ships per year until 1997. [REF. 17 pg. 11]

TABLE 1

YEAR	NUMBER AUTHORIZED
1985	1
1986	0
1987	2
1988	0
1989	5
1990	5
1991	4
TOTAL	17

The costs for each of the 12 cost categories introduced in chapter IV are presented in Figure 12. Each of the bars represents one of the cost categories. The program has had cost overruns since its start in 1985, and the biggest cost driver for those overruns has been the area of basic construction. However, the cost for ordnance has been under the estimated cost and therefore provided offsetting savings to the program.

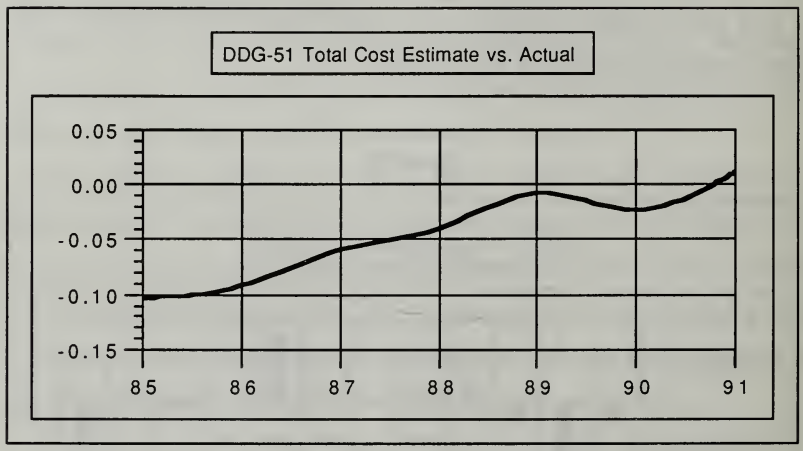
Figure 12



The total cost of the program by year is presented in Figure 13. The actual ship cost is compared to the original estimate for ships that have been completed. For ships still under construction the estimated end cost at completion is compared to the original estimate. This data analysis indicates the DDG-51 program has been consistently underestimated. The difference

between the original cost estimates and the actual cost have been getting smaller, but the latest have not yet been completed.

Figure 13



B. DDG-51 SUMMARY

The DDG-51 is a new program and the cost estimates are subject to many uncertainties. Any delays or unanticipated problems may drive the cost higher than expected. [REF. 21 pg. 15] The contract incentives were established through separate sharing ratios established in the contract. The Navy and contractor share costs above the target costs up to the specified ceiling prices, which is the maximum that the Navy will pay. All costs above the ceiling are paid for by the contractor. The build plan is split between the two contractors,

with each constructing half of the programs ships. The Navy portion of the cost overrun amounted to $116.7 million dollars for the lead ship.

Bath Iron Works encountered major delays in designing the lead ship. This caused the ship delivery schedule to slip by 17 months and contributed to the cost overruns. The design delays were mainly the result of:

- problems with computer aided design
- changes in design requirements
- late government furnished data [REF. 22 pg. 2]

The cost savings from the ordnance category may be attributed to the AEGIS weapon system. This is a mature program that has been built since 1978 and previously installed on the CG-47 class cruisers. [REF. 2 pg. 25]

C. FLEET BALLISTIC MISSILE SUBMARINE (TRIDENT)

The Trident submarine is designed to provide a undersea strategic missile system to ensure that the United States continues to maintain a credible, survivable, deterrent independent of foreseeable threats. The Nuclear powered Trident submarine incorporates state-of-the-art technologies in submarine quietness, mobility and self-defense making the submarine highly survivable. The Trident submarine can patrol, transit, or evade enemy search forces at higher speeds than most other SSBNs. It has an integrated command and control system, including an integrated radio room designed to enhance the survivability of communication links in a hostile environment. It carries the latest submarine defense systems. General Dynamics Electric Boat Division, Connecticut has been the sole source for construction of the Trident, which began construction in 1974. The Trident program has used a FPI type contract. The Navy expects to buy a total of 18 submarines. The last one is scheduled for delivery in 1997. [REF. 23 pg. 11]

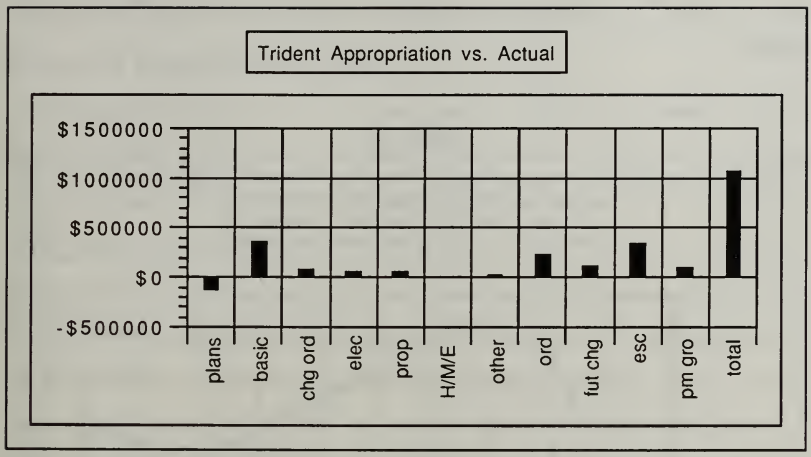
The number of submarines that have been constructed or are under construction by program year is presented in Table 2. All of the planned Trident submarines have been funded. The program has had at least one submarine under construction for the last nine years and experienced only two years when there were no submarines funded for construction.

TABLE 2

YEAR	NUMBER	YEAR	NUMBER	YEAR	NUMBER
1974	1	1980	1	1986	1
1975	2	1981	1	1987	1
1976	1	1982	0	1988	1
1977	1	1983	1	1989	1
1978	2	1984	1	1990	1
1979	0	1985	1	1991	1
				TOTAL	18

The costs for each of the 12 cost categories are presented in Figure 14. The total Trident program experienced a cumulative cost savings of over $1.0 billion dollars over the last ten years. The largest cost category for these savings has been basic construction. Although, almost every cost category has experienced some cost savings.

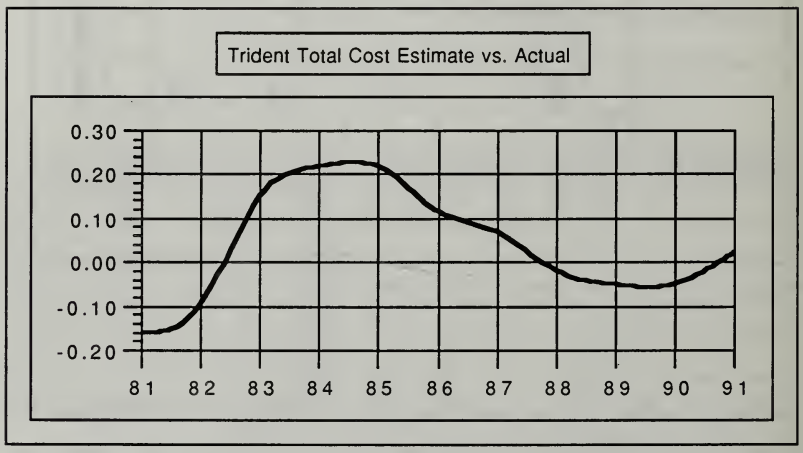
Figure 14



The total cost of the program by year is presented in Figure 15. This program had one significant change over the last ten years. This change was in 1982 when the program had a major modification to incorporate the D-5 missile and the Trident II strategic weapon system. Extensive changes to the submarine had to be made to allow for the new weapon systems and missile. The Trident II program is designed to provide increased accuracy and range/payload for submarine launched ballistic missiles. The Trident II Strategic weapon system consists of six functional subsystems that program and launch missiles to targets and record system operations during test firings. The specific subsystems that were changed by the upgrade are navigation, fire control, launcher, missile, . guidance, and test

instrumentation. [REF. 24 pg. 18] These changes added approximately $ 617 million dollars to the Trident submarine cost estimate for the first year of the upgrade.

Figure 15



D. TRIDENT SUMMARY

During the mid 1980's, the Trident program incurred cost savings that were used to offset the cost overruns of other Navy ship construction programs. The significant event that affected the program was the introduction of the Trident II missile system in 1982. The change to the Trident II missile system required major changes to the submarine and thus new estimates for the cost. Since it was a major modification, the cost was

unknown and the budget was overestimated for the changes. [REF. 23 pg. 8] This resulted in the extensive cost savings for the program.

E. ATTACK SUBMARINE (SSN-688)

The SSN-688 nuclear attack submarine is designed to destroy enemy ships, primarily submarines. The SSN-688 submarine is capable of operating for long periods of time in waters under enemy air and surface control.[REF. 20 pg. 345] Newport News Shipbuilding and Dry Dock Company was awarded the lead ship construction contract in 1970. General Dynamics Electric Boat Division was established as the second source for production that same year. All contracts for construction are FPI. Contracts for production were awarded based on the lowest cost bidder. However, each contractor has constructed 50 % of the total number of ships. The Navy has purchased 62 of the SSN-688 submarines since the construction of the first submarine in 1970. The last new construction submarine is expected to enter service in 1995. With 62 total submarines, this program has the greatest number of units of the four programs reviewed. [REF. 25 pg. 11]

The number of submarines that have been constructed or are under construction by program year is presented in Table 3. All of the planned SSN-688 class submarines have been funded. While there has been at least one submarine funded for construction over the last twenty years, the quantity being built has varied from one to a maximum of six.

TABLE 3

YEAR	NUMBER	YEAR	NUMBER	YEAR	NUMBER
1970	3	1977	3	1984	3
1971	4	1978	1	1985	4
1971	5	1979	1	1986	4
1973	6	1980	2	1987	4
1974	5	1981	2	1988	3
1975	3	1982	2	1989	2
1976	2	1983	2	1990	1
				Total	62

The costs for each of the 12 cost categories are presented in Figure 16. The primary change for the SSN-688 program is in the basic construction category. This category accounts for the large cost overrun of the program. This program incurred overruns of over $800 million dollars during the ten year period of analysis.

The total cost of the program by year is presented in Figure 17. As can be seen from the data, the accuracy of the cost estimates has been very erratic over the years. However, the program as a whole has experienced cost overruns.

Figure 16

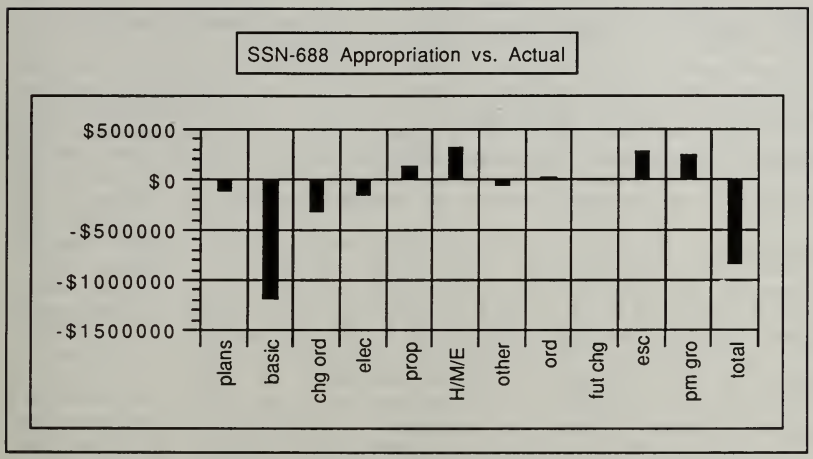
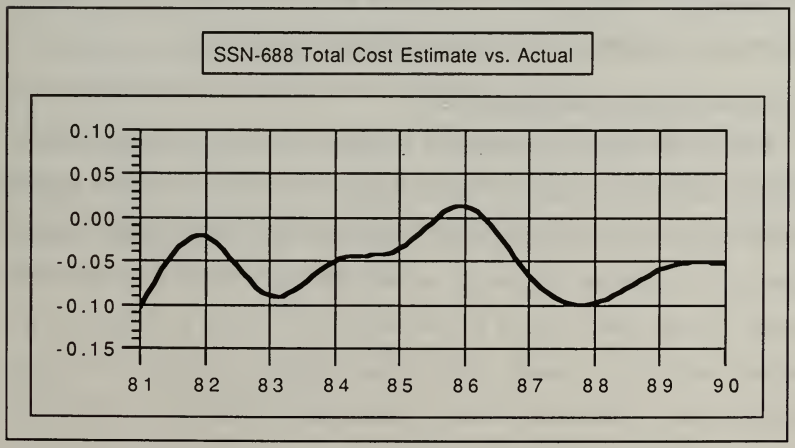


Figure 17



F. SSN-688 SUMMARY

All SSN-688 submarine contracts have been overrunning their target cost. [REF. 26 pg. 2] The program has undergone numerous changes during the last ten years and the total cost shows these changes. These changes include the addition of a Vertical Launch System in 1981 for the deployment of cruise missiles. This required a significant structural change to add the new system. This change was brought about by the change in mission requirements. The installation of the cruise missile capabilities added a strike element that the submarine did not previously require. The addition of the vertical launch system increased the basic construction for the submarine by $121.5 million dollars for the first year of system installation. In 1983, the AN/BSY-1 (Advance Combat System) was introduced. This enhanced and upgraded the sonar system and the data processing capabilities. However, the system had late and/or faulty design data. Thus, it was delivered late for installation into the submarine construction. The addition of the advanced combat system and the subsequent delays caused cost growth for basic construction of $142,109 dollars and electronics cost increases of $76.6 million dollars.

G. GUIDED MISSILE CRUISER (CG-47)

The CG-47 cruiser is specifically designed to carry the AEGIS weapon system. With this and other advanced systems, the ship is a broadly capable, heavily armed and survivable cruiser. The CG-47 class is designed to conduct prompt and sustained worldwide combat operations at sea, as a part of an aircraft Carrier Battle Group or Surface Action Group; to neutralize and destroy hostile air, missile, surface and subsurface threats and defeat simultaneously coordinated attacks by such forces. [REF. 20 pg. 678] Ingalls

Shipbuilding was awarded the lead ship construction contract in 1978. Bath Iron Works was established as the second source for production in 1982. However, Bath did not begin construction of the first CG-47 until 1985. Therefore, Ingalls built over three fourths of the ships. The initial contracts for construction were CPAF with a change to FPI in 1983. The Navy expects to buy a total of 27 CG-47 class ships. The last one is expected to enter service in 1994. [REF. 27 pg. 11]

The number of ships that have been constructed or are under construction by program year is presented in Table 4. All of the planned CG-47 class ships have been funded. The procurement for the program has been stable over the last ten years, the exception was the last year of the program when the Navy bought out the remaining contract and budgeted for five ships to complete the program. [REF. 22 pg. 14] The contract was bought out for two reasons:

-capitalize on economies of scale from a larger purchase

-complete the program earlier to avoid further delays in other programs

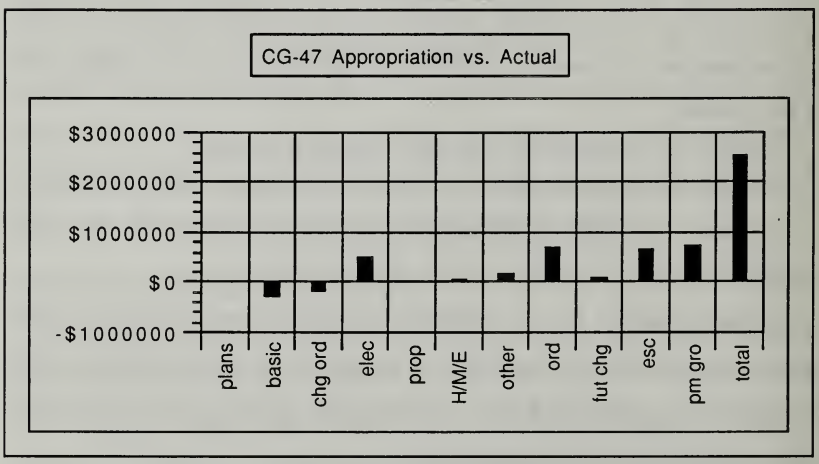
The same contractors build the DDG-51 class destroyer and it may have been delayed due to CG-47 construction. [REF. 22 pg. 22]

The cost categories for each of the 12 cost areas are presented in Figure 18. The data analysis reflects the fact that no one cost category dominates. Overall, the program has experienced cost underruns with savings of over $2.5 billion dollars over the duration of construction .

TABLE 4

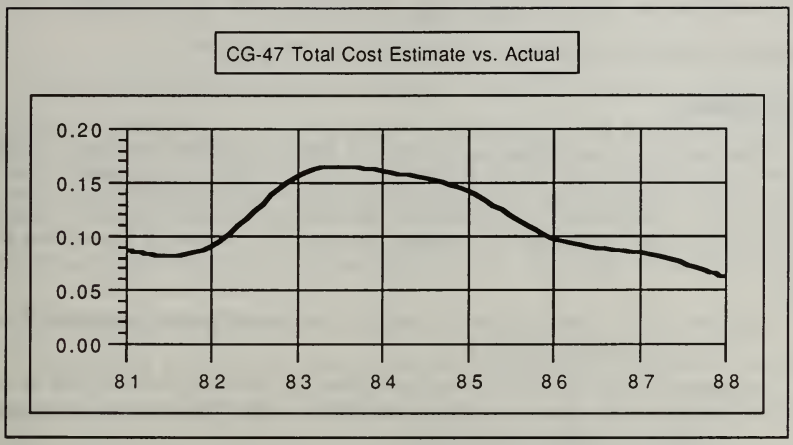
YEAR	NUMBER	YEAR	NUMBER
1978	1	1984	3
1979	0	1985	3
1980	1	1986	3
1981	2	1987	3
1982	3	1988	5
1983	3	TOTAL	27

Figure 18



The total cost of the program by year is presented in Figure 19. The data reflects a total construction program which has been stable over the years and predominantly over budgeted.

Figure 19



H. CG-47 SUMMARY

The program has had no cost overruns during the last ten years. This program has been always over budgeted. It has had cost savings that could be used to offset other program losses. [REF. 21 pg. 16] Several specific events happened that are significant for this program. The first was the change in contract type in 1983. The contract was changed from a CPAF to a FPI. [REF. 27 pg. 17] At that point, the difference between the estimates and the actual cost increased substantially. The change in contract type adjusted the burden for cost risk from the government to the contractor. Second, an additional contractor was funded for the CG-47 program in 1985. Although the second contractor was identified earlier than 1985, this was the first year of production. [REF. 27 pg. 23] The second contractor was introduced to create a

second source for the CG-47 and to expand the industrial base for U.S. Navy ship construction. [REF. 28 pg. 5] Also, the introduction of the second source brought the actual cost closer to the estimate for the program.

I. SUMMARY

This section of the thesis has presented the four specific programs and some of the changes that have occured to each program over the ten year period. All of the programs are unique. Factors that make each one different are:

- **mission**, each of the missions is unique, thus the ships are constructed to fulfill a specific mission.
- **construction period**, each program started construction for the lead ship at different times, ranging from 1970 to 1985. Therefore each is at a different phase of production.
- **production quantity**, total program production ranges from a low of 18 to a high of 62.

This chapter has addressed the accuracy of the cost estimates compared to the actual construction costs for each program and highlighted significant events occuring in each of the programs. The next chapter will analyze the programs further to determine if there are any similarities among the programs and if there are any trends or consistent factors across shipbuilding programs.

VI. DATA ANALYSIS

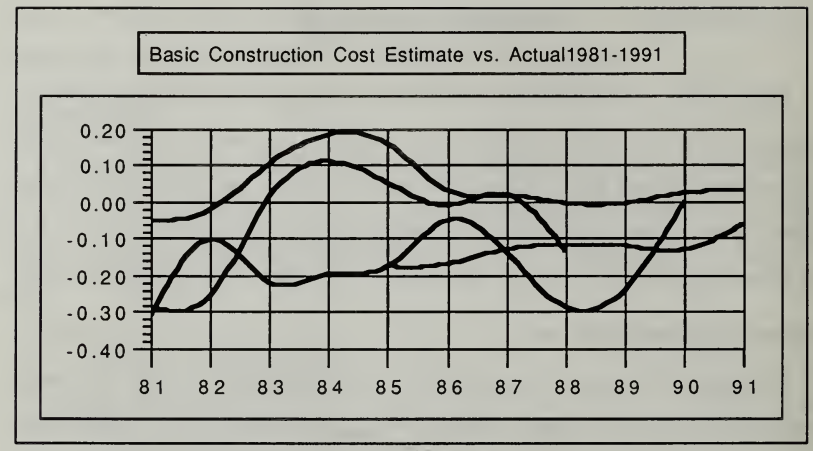
This section of the research compares the data for each ship program to determine if there is any overall pattern affecting all ship programs. It will also address factors which impact the actual cost of the four selected ship classes. The analysis will review the relationship between these factors and the presence of cost overruns or underruns for the final ship acquisition cost.

A. BASIC CONSTRUCTION

Analysis of the data for each of the four programs indicates that basic construction is the most significant cost category for new ship building costs. For the submarine programs analyzed, the basic construction costs account for approximately 47 % of the total cost. For the combatant ships, basic construction costs are approximately 33 % of the total cost. Basic construction costs were compared to determine if there are any trends in this category. The comparison of the four programs is presented in Figure 20.

The analysis reflects that the two programs that experienced overall cost overruns also had basic construction cost overruns and the two programs that had overall cost savings also had basic construction cost savings. This would indicate that the basic construction category is a principal category in determining the accuracy of ship cost estimating.

Figure 20



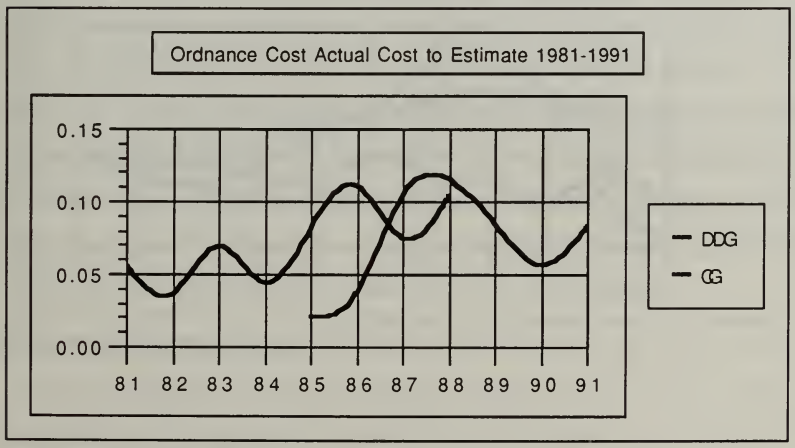
B. ORDNANCE

Analyzing the data for the four programs indicated that ordnance costs have been over budgeted for all of the programs during the ten year period. This cost savings is not major for the submarines, however, it is significant for both the CG-47 and the DDG-51 programs. The cost savings for the CG-47 program has amounted to $712.5 million dollars over the time period analyzed, and cumulative savings are $335.3 for the DDG-51 program. The ratio of actual costs to original cost estimates for the ordnance category in the DDG-51 and CG-47 programs are presented in Figure 21.

Comparing the two programs indicates that the cost savings for the two programs has been substantial every year from a low of two percent for the

first ships of the class to a high of twelve percent on subsequent ships. This could mean a cost savings of $12 to $30 million dollars per ship for the ordnance category. The data also indicates that the ratio of actual costs to estimates for ordnance is cyclical for these two programs; furthermore, the cost savings is increasing. Future cost savings will be higher given the present trend. The research did not identify any significant program wide events or factors that contributed to this cyclical behavior. Identifying such factors would require investigating the prime ordnance contractors or specific ordnance programs. This is beyond the scope of the thesis.

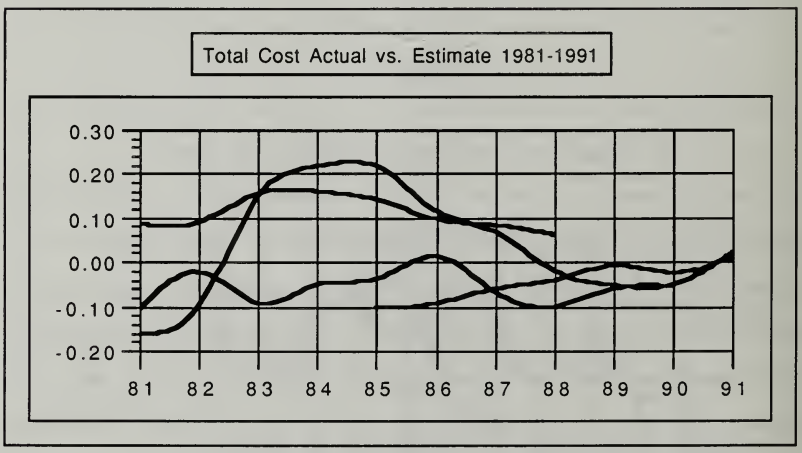
Figure 21



C. TOTAL COST

Each of the programs' total cost can be compared to determine any trends that may be consistent for the cost of each ship by program year. This may highlight any major changes in procedures or policy that have affected ship construction costs. The comparison for all of the programs is presented in Figure 22.

Figure 22



As the total cost comparison shows, the CG-47 and Trident had substantial cost savings during the defense build up of the early 1980's.

However, their cost savings started to decline in 1985. This may be attributed to changes in ship construction budgeting procedures.

D. PROGRAM MANAGERS GROWTH

This area of ship construction budgeting was revised in 1985, eliminating the contingency reserve funds that the program manager was previously able to utilize for contingency plans during ship construction. With elimination of this category, programs are more likely to face cost overruns because the budget has no budgeted flexibility for unknown problems that may occur during ship construction.

Since this contingency reserve category was eliminated, the overall SCN budget has experienced net cost overruns, as both Figure 22 and Figure 7 (Chapter III) indicate. This budgeting change may have caused the decrease in savings. As the data indicates, the actual costs for the three programs still being procured by the Navy in 1989 were all underestimated. Based on the current trend in total costs for each of the programs, future funding would be expected to be below the actual cost of construction. The total cost for each of the programs is within five percent of the actual cost. This five percent difference equates to $157 million dollars for the DDG-51 program as a whole, or $39 million dollars for each ship, based on 1991 cost estimates.

E. COMPARISON SUMMARY

The comparison of the ship programs reveals the fact that the basic construction cost category has the most significant influence on a ships total end cost. The comparison also highlighted the fact that the ordnance category has been overestimated every year for the two surface ships and that there appears to be a repetitive cycle between the actual ordnance cost and the

original budget estimates. The data for the total ship costs also indicated that the reserve cost categories may result in cost savings to a program and that the elimination of the reserve accounts may have caused programs to experience cost overruns. The next section will address the factors that were presented in Chapter II and their effects on the four programs analyzed.

F. COMPETITION/DUAL SOURCE

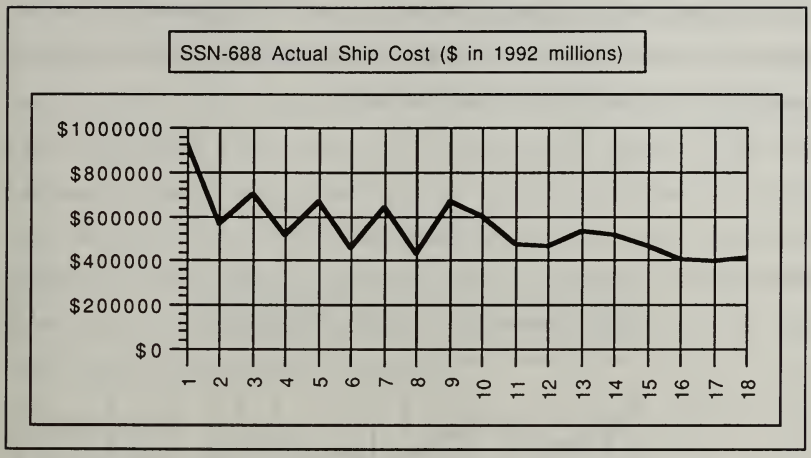
1. Initial Competition/Dual Source

The SSN-688 and the DDG-51 were competitively bid and dual sourced from the beginning of production. As Figure 22 indicates, these two programs have predominantly had cost overruns over the last ten years. The hypothesis that cost growth in competitively bid contracts is attributed to low bids by the contractors appears to apply for these two programs. However, since the DDG-51 is a new program, only a few actual ships have been completed. Thus, further analysis is only conducted for the SSN-688.

The actual cost for the SSN-688 programs first 18 ships is presented in Figure 23. The actual cost is adjusted to 1992 dollars and is presented to investigate what happens to actual ship cost with a second source of production.

The data in Figure 23 indicates that the actual cost for each ship was very erratic at the beginning of construction. The peaks and valleys for the first ten ships correspond to different contractors building the ships. This indicates that the second source will have initially higher costs. However, the costs stabilize as the program matures. In this case, the program stabilized by approximately the eleventh ship.

Figure 23

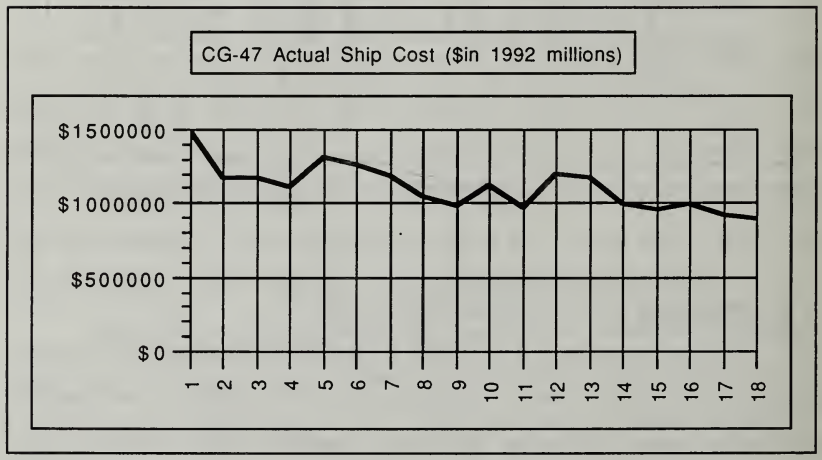


2. Introduction of Competition/Dual Source

As was presented in Chapter V, the CG-47 program has had cost savings over the last ten years. Ingalls was the only contractor building the ship during initial production. However, a second source contractor was established during the production phase. This is the only program that introduced a second contractor during the production phase. Chapter II suggests that competition may encourage efficiency and lower costs to the Navy when there is a second source introduced into a previous sole source program. The data presented in Figure 19 Chapter V, indicates that introducing the second source in the CG-47 program resulted in actual costs being closer to the estimated cost. However, the actual cost of the first 18 ships of the CG-47 program indicate that the actual cost increased with the

second producer (number five), which would be expected, as shown in Figure 24. The actual costs, although declining over the program life, do not necessarily indicate that the cost to the Navy has actually declined with the introduction of the second source of production.

Figure 24



3. Sole Source

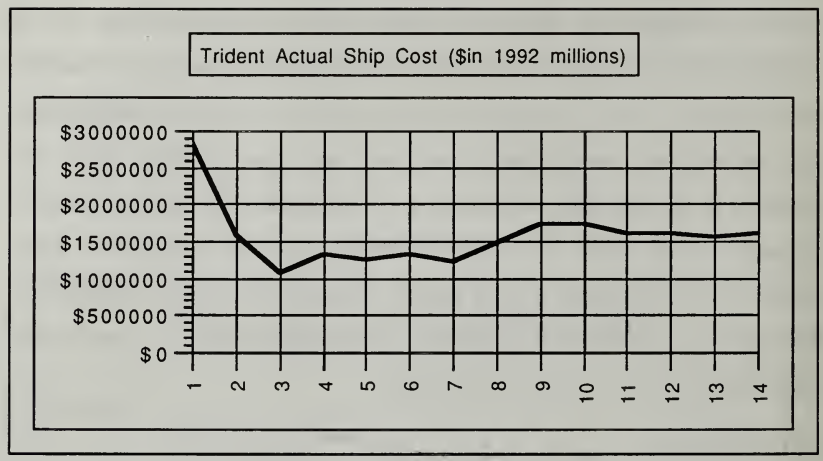
When production for a program is sole source it can be expected that the cost for the program will be high. The contractor can theoretically set the price for the contract, since there are no other options to procure the ship. The Trident program was the only program analyzed that had only one producer. As the data in Figure 15 Chapter V indicates, the actual cost of production for

the Trident program has been below the estimated cost. This may indicate that the contractor has overestimated the costs and thus resulted in cost savings to the program. This overestimated cost may be due to the FPI contract for the Trident program and no competition during the bid process. This overestimate would cause cost underruns and therefore allow the contractor to share in the cost savings of the program. The data in Figure 25 indicates that the actual cost of the Trident has been very stable. The major difference of this program and the others is that the actual cost of production stabilizes soon after program initiation, and does not have the peaks and valleys that the other programs experienced.

G. CONTRACTS

The type of contract to be used in ship procurement is set by the Navy to meet the circumstances of the particular procurement. When a contractor undertakes significant risks, the Navy contract will be selected and structured to share that risk with the shipbuilder. When a program is new and uses limited quantities of proven technology, such as the early CG-47 ships, the government will share the uncertain risks of technological advances by using a cost plus type contract. When circumstances dictate that there is little risk to the shipbuilder, the contract form selected will place a greater burden on the shipbuilder by utilizing a fixed price contract. With this contract, the contractor absorbs any cost overruns.

Figure 25



Of the four programs that were analyzed, the only one that changed contract type was the CG-47. In 1983 the contract was changed from CPAF to FPI. When the contract changed there were substantial cost savings for the program as shown in Figure 19 Chapter V. This would seem to indicate that a FPI contract would have lower costs to the government.

H. MARKETPLACE

The term "shipbuilding marketplace" refers to the private shipbuilders in the United States who are qualified to contract and build ships for the U.S. Navy. [REF. 28 pg. 13] Ten years ago there were 25 U.S. shipbuilders qualified to build U.S. Navy ships. Today there are approximately 13 qualified shipbuilders. Several factors related to the marketplace can influence the initial contract award price and ultimately the final cost of Navy ships.

1. Workload

The current shipbuilding workload, including the backlog of new ship construction and the prospect of future work, are continuing concerns for shipbuilders and the Navy. [REF 29 pg. 18] A steady stable workload is a prerequisite to maintaining or improving the efficiency of a shipyard and to lowering costs. [REF 29 pg. 22] Conversely, an erratic workload with start-ups and slowdowns may lower efficiency and increase costs. [REF 16 pg. 5-3] A shipbuilder facing a future drop in workload may be more competitive in bidding for work that can fill a potentially harmful workload gap. Also, with few new ship construction orders, shipbuilders may stretch out existing work. On the other hand, a shipbuilder who is overloaded with work may not show the same interest.

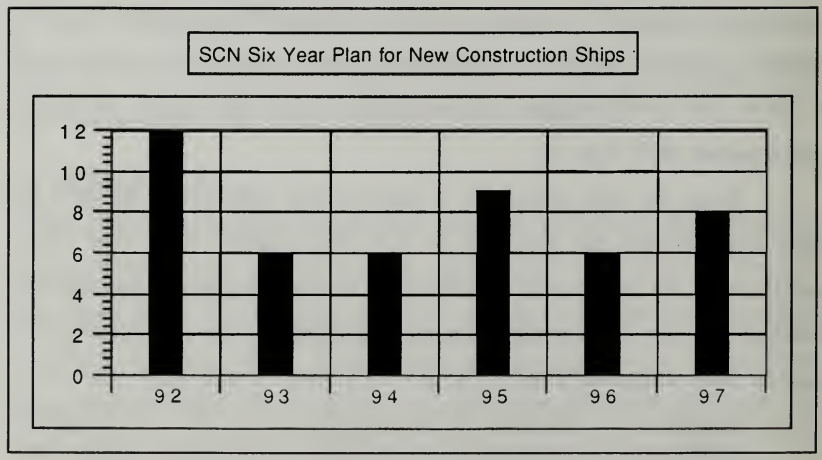
Most major shipbuilders are dependent on both commercial and Navy ship construction orders for their business. At times when attractive commercial work is readily available, shipbuilders may pursue it first. As a consequence, Navy shipbuilding may ultimately experience higher costs and possibly late ship deliveries. Conversely, when commercial work is not available, Navy shipbuilding may experience lower bids from contractors than expected. [REF. 5 pg. 16]

From the data presented, it appears that commercial demand for ships has affected the end cost of U.S. Navy ships since 1961. Most significantly, the commercial shipbuilding industry workload has steadily declined since the shipbuilding subsidies were removed in 1981. Commercial builders have competed fiercely for the only business available, U.S. Naval ship construction. This competitive bidding may have occured with both of

the programs that have experienced cost overruns (DDG-51, SSN-688). Of the four programs that were analyzed, these two had competition for the initial production contract and thus the contractors may have been underbidding actual expected costs. Since there was no other commercial business, survival encouraged them to submit low bids to in order to secure the initial contract. Presumably they expected to receive increasing profits later. At the time, the U.S. Navy was expanding to a force objective of 600 ships, as announced by Secretary of the Navy Lehman. Thus, the shipyards expected significant profits from follow-on U.S. Navy construction contracts. [REF. 21 pg. 5]

In the current budget environment, the number of new construction Navy ships is expected to remain very small for at least the next six years as shown in Figure 26.

Figure 26



Based on the six year SCN construction schedule, continuous steady workloads for the shipbuilders seems unlikely given the small number of new ships to be constructed. Furthermore, of the four programs that were analyzed only the DDG-51 Guided Missile Destroyer will continue production for the next six years. Thus, plans by the contractors to make any significant profits on later construction contracts are unlikely based on the current shipbuilding plan.

I. TRENDS

When the commercial shipbuilding industry prospers or has sufficient work, the U.S. Navy can expect to receive more realistic cost estimates from the contractor. This occurs since the incentive for the U.S. Navy contract is not as critical for shipyard survival. At the present time, there is limited commercial work in the current shipbuilding industry. Therefore, the shipyards must rely on the U.S. Navy for their survival in the shipbuilding business. As Figure 26 indicates, the number of new construction ships to be built over the next six years is minimal. With the slowdown in ship construction the shipbuilding industry will continue to face a declining Navy workload and greater incentive to buy-in to the construction contract. Therefore, the cost of U.S. Navy ships can be expected to increase above estimated costs. In addition, actual costs should increase because overhead costs will be allocated to fewer ships.

J. SUMMARY

This section of the thesis has presented the similarities of each program over the last ten years. Also, actual construction costs of each program were presented to investigate how the factors that affect ship costs addressed in

Chapter II have actually affected the selected programs. The next chapter will summarize the data presented and the future outlook for ship construction.

VII. CONCLUSIONS

Budget estimates that are significantly different from actual costs negatively affect the Navy's ability to make informed resource allocation decisions. In the current atmosphere of decreasing defense budgets, the accuracy of the estimates can have a significant affect on the whole SCN budget due to the limited number of ships that are currently being constructed and are expected to be constructed in the future.

This Thesis research has reviewed the last 30 years of the SCN appropriation account to determine if there are any consistent patterns. Specific emphasis was placed on four shipbuilding programs constructed over the last ten years.

A. ANALYSIS

Analysis of the SCN Appropriation and the selected programs indicates that there are trends or factors that may affect the ship total cost. There are several areas that were investigated. First, the basic construction cost category has a significant affect on the actual total end cost. However, the category is not consistently over or under the original estimated cost. Second, ordnance costs have been over estimated for all the programs studied. The surface combatant ship ordnance budget estimates have been significantly greater than the actual ship costs and appear to have a cyclical trend. Third, the elimination of reserve funds may have caused each of the programs studied to have cost overruns in recent years, particularly for the Trident program which had previously been experiencing cost savings. Fourth, competition/dual sourcing may not result in lower costs for the Navy,

especially in the current shipbuilding environment. When a new producer is introduced the costs inevitably increase due to initial plant investment and start up costs. This happened with all of the programs that have dual sources of production. The expected cost savings may result later in the programs development. However, the data did not indicate such savings occured in the programs investigated. Fifth, the type of contract utilized by the Navy for ship construction has been predominantly FPI. Programs utilizing this type of contract experienced both cost overruns and underruns for the programs investigated. The one ship program that did change contracts from CPAF to FPI realized estimated costs closer to the actual cost of construction after the contract change. Finally, the declining shipbuilding industry, and specifically the reduction in commercial shipbuilding contracts, may have forced contractors to under bid for limited Navy contracts in order to stay in business.

The declining commercial shipbuilding industry has had significant impact on Navy ship construction costs. As presented in Chapter VI, the future of the shipbuilding industry in the United States is not very bright given the declining Navy shipbuilding plan and the limited commercial construction business available. However, there is a new program initiative that has been created entitled the "National Defense Sealift Fund." It may provide some needed new construction contracts for the shipbuilding industry. This new initiative is designed to provide funds for the construction or conversion of 20 large, medium speed, roll-on/roll-off ships. The FY 1993 Department of Defense Budget includes $1.2 billion for the National Defense Sealift program. Along with the $1.875 billion appropriated

in FY 1990, FY 1991, and FY 1992, the total funding available will be over three billion dollars. This fund could help fill the idle capacity of existing shipyards. It could also maintain the industrial base for eventual surge production of ships if necessary. While this fund may not bring the shipbuilding industry back to full construction capacity of previous years, it could mean the difference between survival and closure for some of the U.S. shipyards and ultimately major cost increases for future Navy new construction ships.

APPENDIX A

SHIPS COST ADJUSTMENT

The Ships Cost Adjustment (SCA) is an annual review of the status of SCN accounts. It is a detailed review of individual program execution requirements. The SCA is used to identify program assets and shortfalls such that they may be adjusted to reflect the most recent execution of program experience.

The SCA covers all undelivered ships and systems appropriated up to ten years earlier and in execution for up to eight years in the future. Since shipbuilding is a high unit cost, low rate, long execution process, the SCA is designed to adjust to the changes in a program that cannot be done in the execution process. The results of the SCA review may disclose a need for reprogramming action to bring estimated ship cost and appropriated funds into balance.

FIRM FIXED PRICE

Firm Fixed Price (FFP) contract entails a fixed dollar amount established at the time of award and payable to the shipbuilder for meeting the total stated contract requirements. A FFP contract is suitable for low risk, short-term construction contracts i.e. repeat buys of boats and craft. Any anticipated inflation during the short period of the contract is considered in the fixed price.

There is also a modified form of the FFP-type contract and that is an FFP contract with escalation. For low-risk, long-term (2 or more years) the Navy

will include escalation in the contract which provides for inflation due to the extended length of the contract.

The most significant aspect of the FFP-type contract to the shipbuilder is that the bid price includes a realistic approximation of estimated costs. A lesser amount could become a serious problem if unanticipated events during construction cause the shipbuilders costs to rise.

FIXED-PRICE INCENTIVE

Most major Navy ship programs are contracted for with Fixed-Price Incentive (FPI)-type contracts. The FPI contract is similar in some respects to the FFP (with escalation) contract form. A significant difference or added feature is the expressed Navy intent to share the cost risks and benefits of the contract along stated sharelines. Inherent within the FPI contract is the premise that a reasonable target cost can be established and that there is a reasonable opportunity for the competent shipbuilder to be able to deliver the completed ship for less than that cost. A fixed target cost, target profit, and target price are established at the beginning. If shipbuilder final costs (in base dollars) fall below target, the shipbuilder and the Navy share those savings along some predetermined percentage shareline. If events force costs upward past the target, the shipbuilder and the Navy share those additional costs along the same or similar shareline. In the latter case, the Navy share ends when total costs reach a predetermined ceiling price. This is the point where the financial commitment of the Navy is complete and the shipbuilder remains totally responsible for any additional costs.

COST PLUS AWARD FEE

A Cost Plus Award Fee contract is used when the status of the program may warrant its utilization. Such cases could be a lead ship with an innovative hull, new propulsion system, or the first type of combat system. The established cost targets in a CPAF contract include anticipated inflation, and a fee at the time of the award. The Navy pays all allowable costs from that point on. The shipbuilder can be awarded additional profits, up to predetermined maximum percentage, if contract performance justifies such profit.

The cost-type contract provides the shipbuilder with maximum cost risk protection and the most flexibility on resource use. The cost-type contract can produce higher cost per unit than a fixed price contract, however this may be attributed to a factors such as uncertainty associated with new plans, specifications or requirements.

REQUESTS FOR EQUITABLE ADJUSTMENTS

Requests for Equitable Adjustment (REA) represent claims by contractors for payment of costs that, according to the claimants, were incurred for work performed that was not provided for in the contract. The Navy does not budget explicitly in advance for payment of contested REA adjustments.

REA is a request for payment, extension of the delivery schedule, or both which is not in dispute at the time the government receives the adjustment. Whenever such a request cannot be settled by an agreement, the contractor may file a claim.

Illustration of P - 8 Budget Document

SHIPBUILDING AND CONVERSION, NAVY
ANALYSIS OF SHIP COST ESTIMATES
($ THOUSANDS)

EXHIBIT P-8
FEBRUARY 1992
AMENDED FY 1992/1993
BIENNIAL BUDGET ESTIMATE

PROGRAM YEAR 1988	SHIP TYPE CG	NO. OF SHIPS 5				
		ORIGINAL APPROPRIATION (1)	FY 92 CONGRESSIONAL (2)	FY 93 CONGRESSIONA (3)	CHANGE COLS 3-1 (4)	CHANGE COLS 3-2 (5)
PLAN COSTS		56,000	82,400	71,400	15,400	(11,000)
BASIC CONST/CONV		1,090,800	1,236,826	1,236,826	146,026	0
CHANGE ORDERS		54,600	73,000	74,286	19,686	1,286
ELECTRONICS		682,600	638,078	641,275	(41,325)	3,197
H,M & E		70,500	53,038	52,019	(18,481)	(1,019)
OTHER COST		75,000	43,346	43,346	(31,654)	0
ORDNANCE		1,879,200	1,666,611	1,684,393	(194,807)	17,782
ESCALATION		120,000	102,612	88,189	(31,811)	(14,423)
PROJECT MANAGERS GROWTH		117,200	0	0	(117,200)	0
LESS: G-R-H ADJUSTMENT					0	0
END COST		4,145,900	3,895,911	3,891,734	(254,166)	(4,177)
LESS: ADVANCE PROCUREMENT FY 1987		18,900	18,894	18,894		
LESS: ESCALATION FY 1992			4,177			
TOA		4,127,000	3,872,840	3,872,840	(254,166)	(4,177)

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